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Title: Development of the MARK4 Design

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Development of the MARK4 Design

A review of the Lujan target Mark-IV neutronics design

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Los Alamos NATIONAL LABORATORY EST.1943

NNSA National Nuclear Security Administration

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Introduction

Development of the MARK4 Design

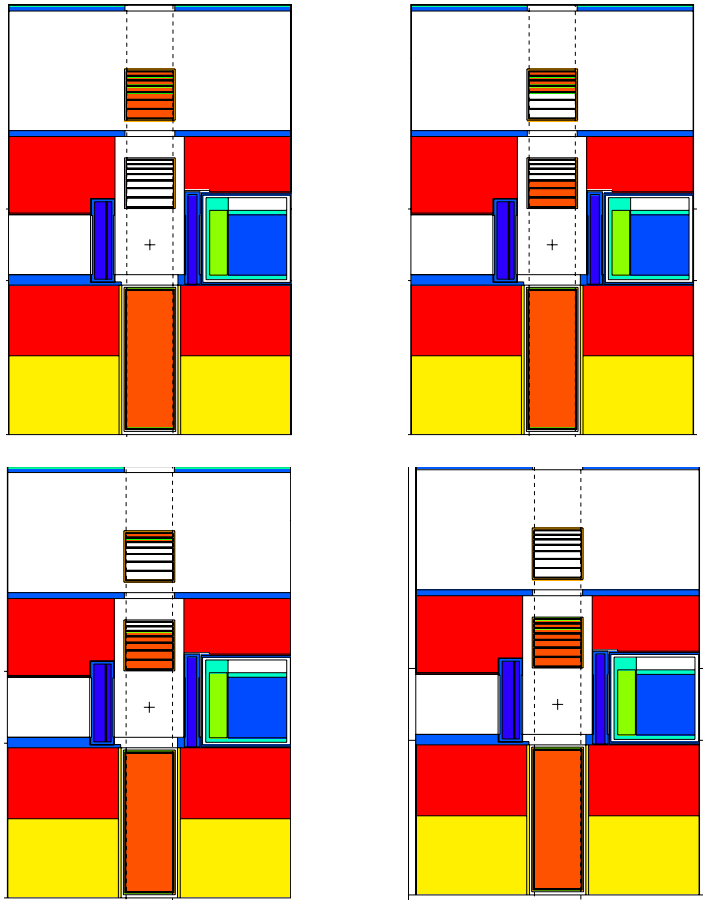
A review of the Lujan target
Mark-IV neutronics design

11/15/2017

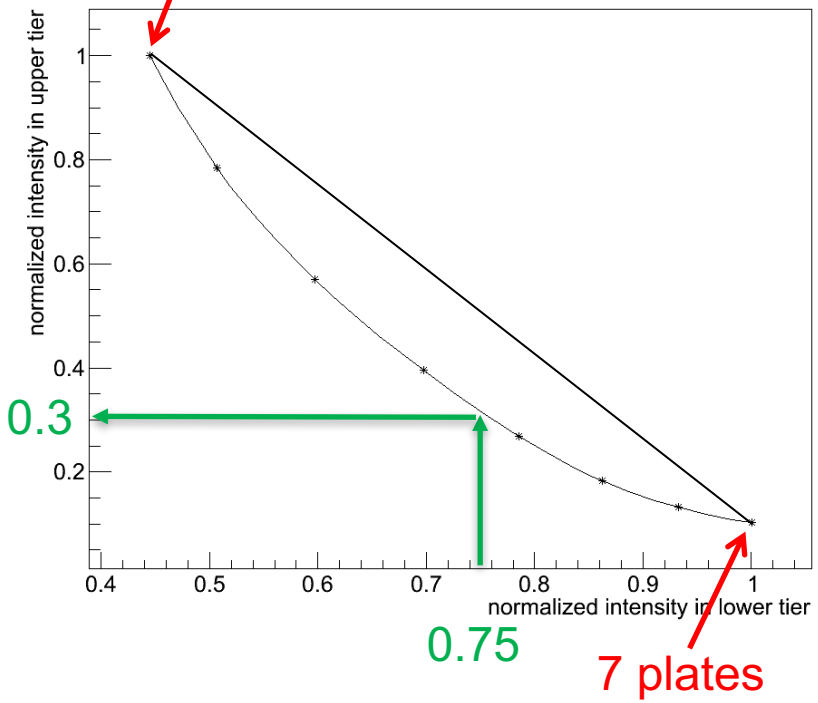
- **Where did we start?**
  - Introduction of preliminary designs
- **How did the preliminary designs develop?**
- **Disk target**
  - Main components of the target
  - Target thickness and orientation
- **Rod target**
  - Role of a coupled water moderator
  - Additional reflector (Be, Pb)
- **Alternative target designs**
  - Different shapes and positions
  - Pros & Cons of the proposed designs
- **Where did we arrive?**
  - Summary of the favorite designs
- **Conclusion**

Preliminary designs (M. Mocko and S. Nowicki)

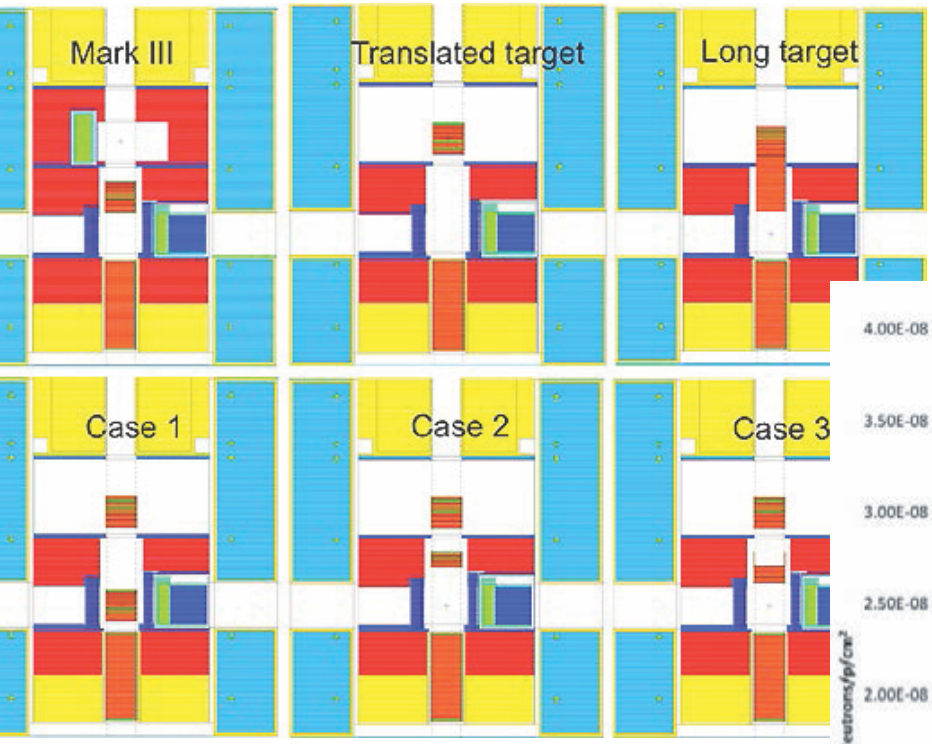
- **Intensity study** using the W disks available in Mark-III
  - Attention was not paid to resolution



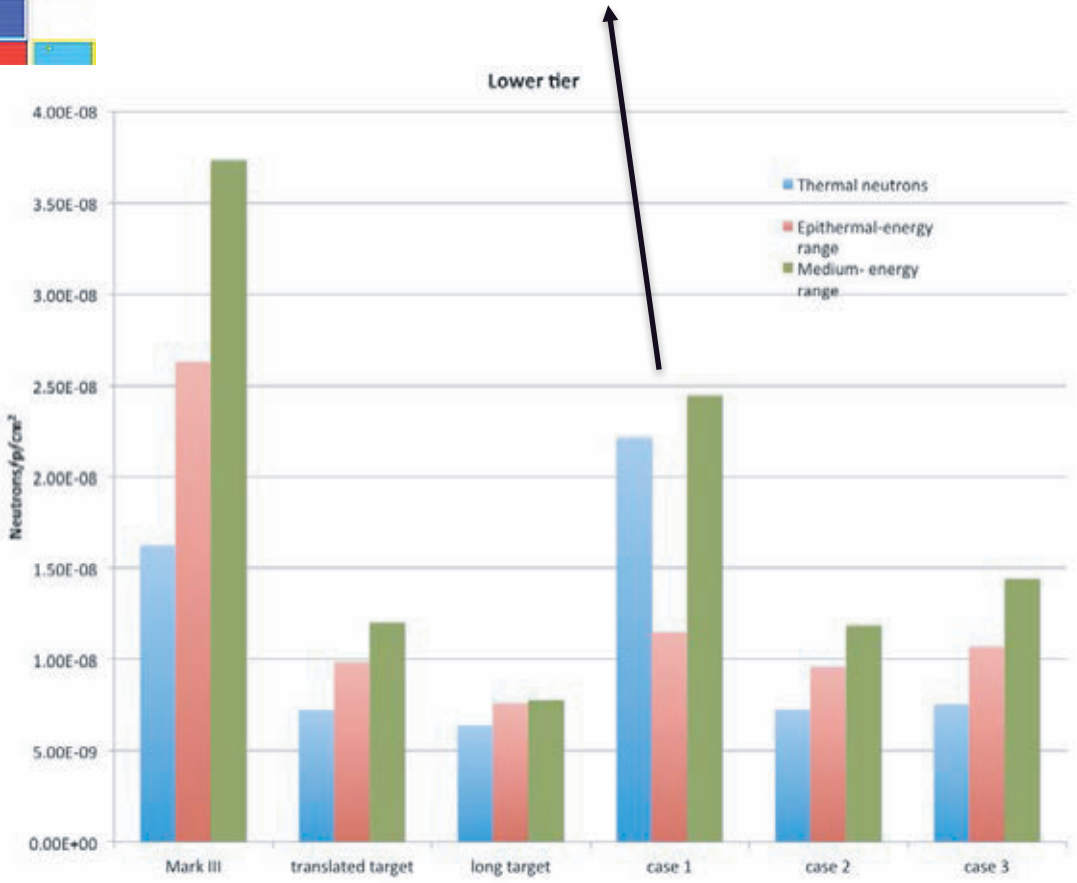
0 plates in the middle target (translated target)



Preliminary designs (continued)



- **Target in the field of view is the most efficient way to increase neutron flux** (both in LT and UT)



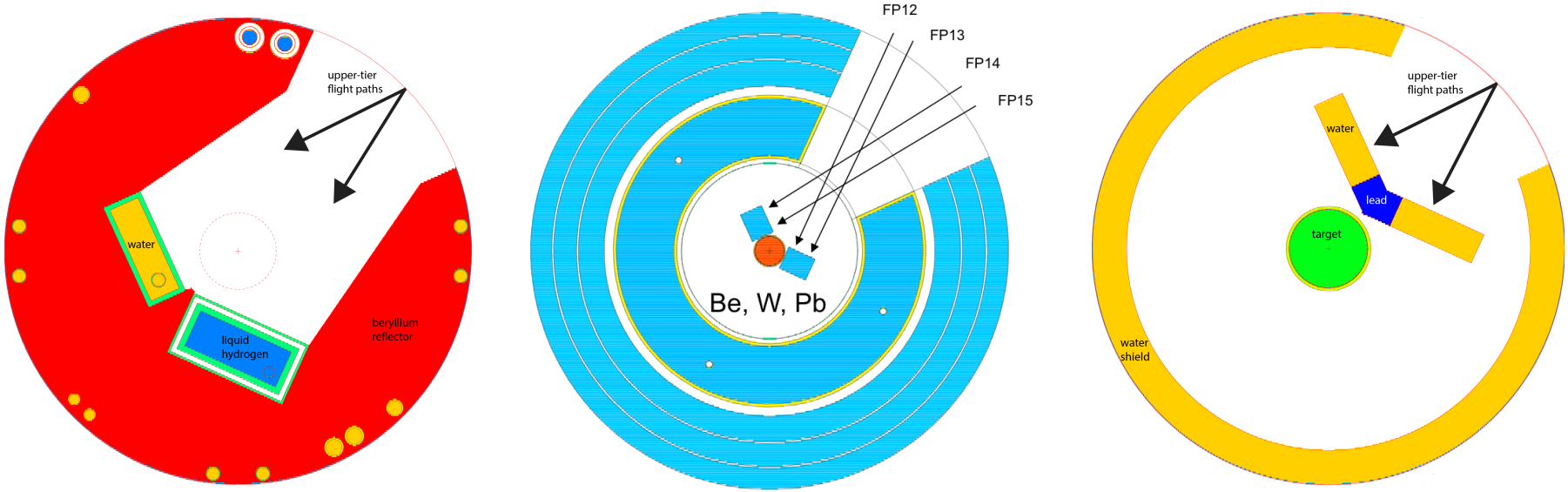
- **Upper tier:**
  - Gain in flux by a factor of 10
- **Lower tier except "Case 1":**
  - Drop in lower-tier thermal neutron flux by more than a factor of 2

Preliminary designs (continued)

IF
- **The target is translated into the field of view &**
- **Flight paths remain in their current configuration (i.e., current FOV)**

THEN Additional measures must be taken to suppress backscattered neutrons

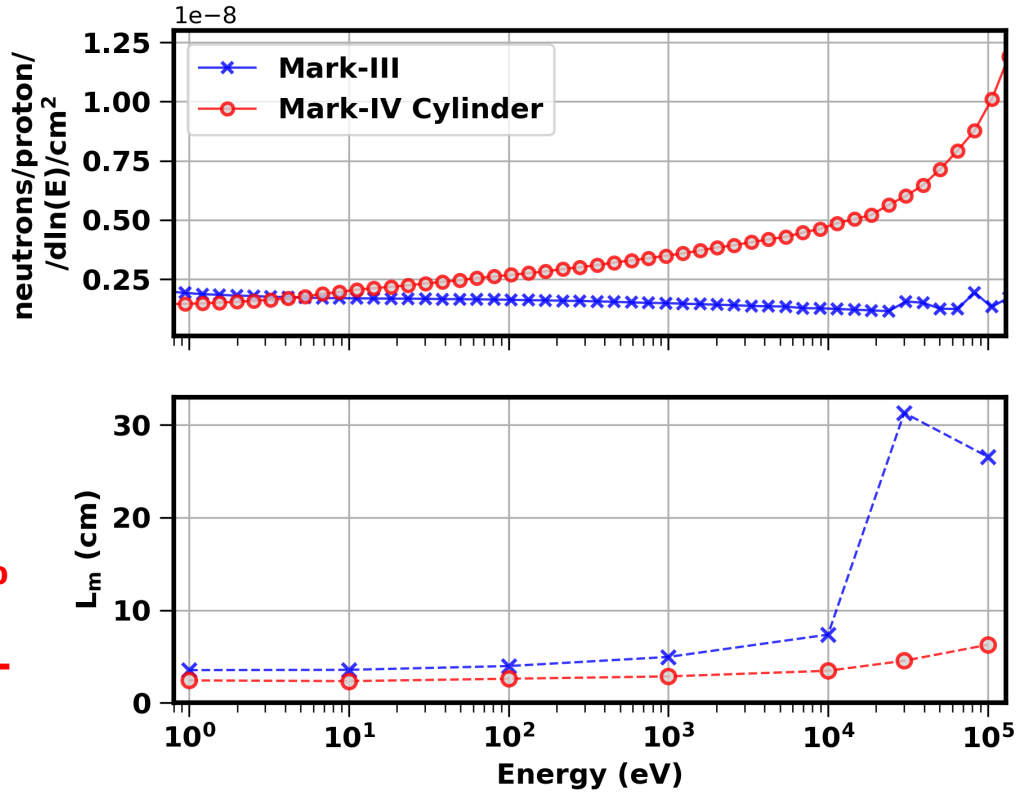
➢ **Introduction of moderator/reflector wings (H_2O, Be, W, Pb)**



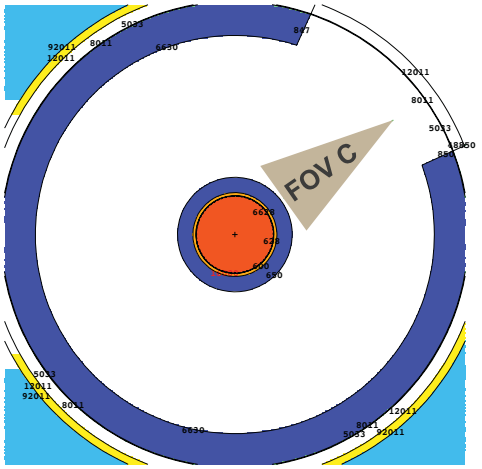
- **The wings could be omitted if the flight paths were reconfigured and focused directly on the production region (i.e., centered FOV)**

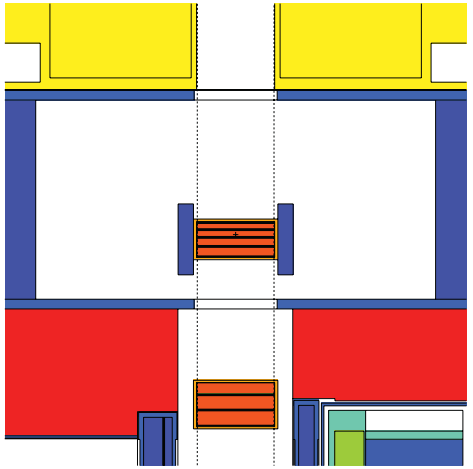
Cylindrical target

- **Original idea:**
  - Split the middle target of Mark-III into two pieces and move one of them into the upper tier of Mark-IV, which should:
    - **Increase flux in upper tier**
    - **Conserve a significant part of thermal flux in lower tier**



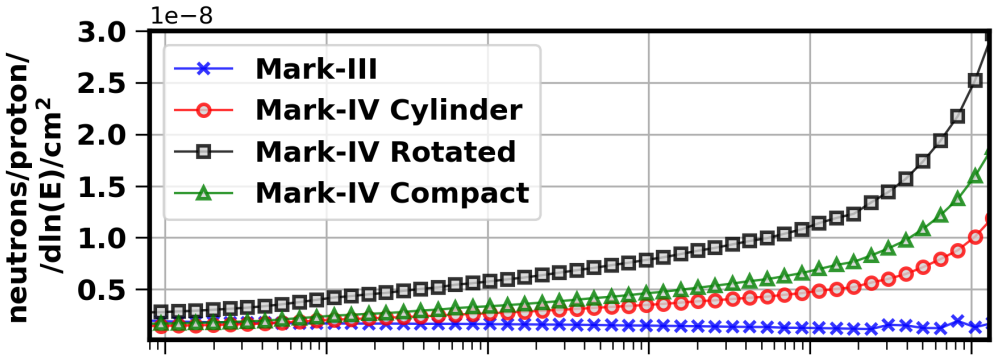
65% flux in LT





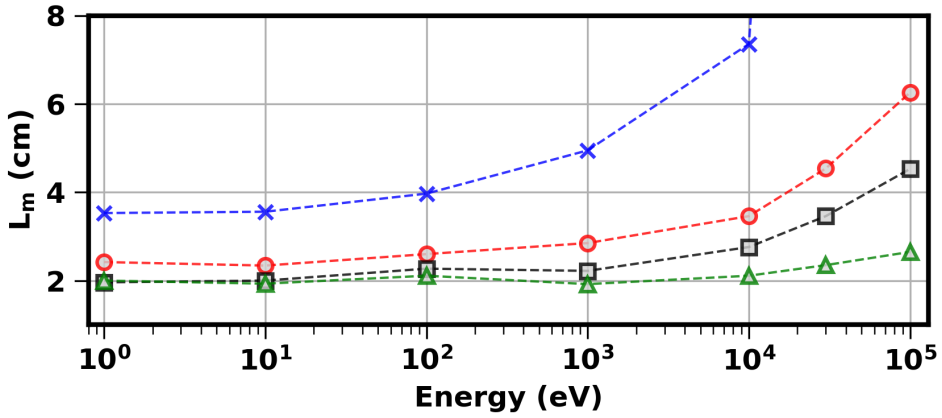
Compact disk target

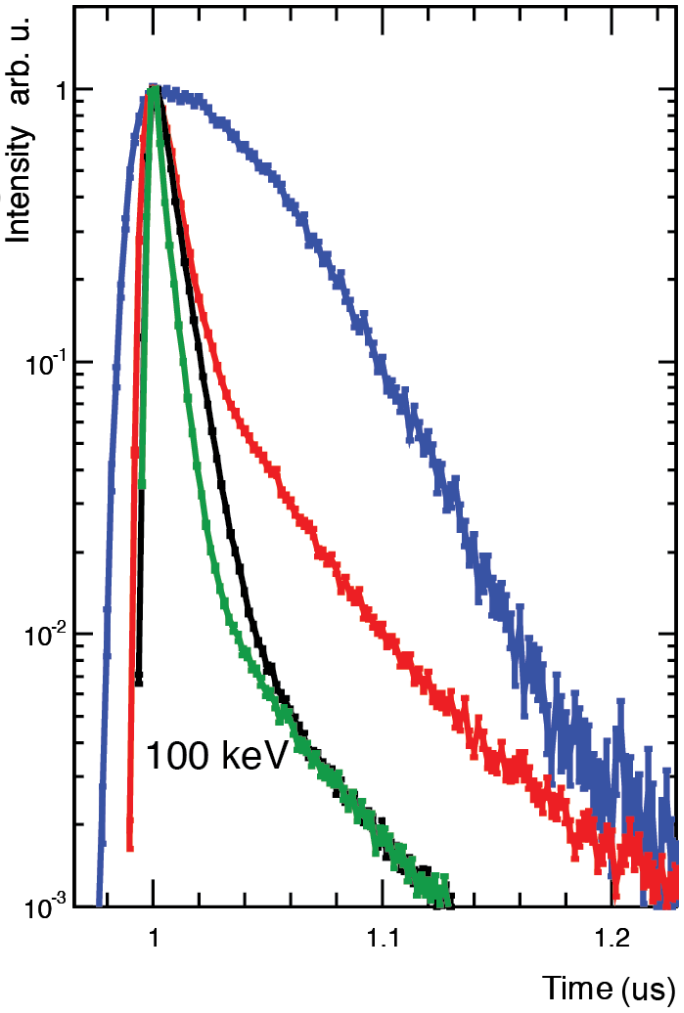
- **90º rotation of the cylindrical target should provide:**
  - Significant improvement in UT time resolution
    - Flat emission surface
    - Reduced thickness
  - More uniform spatial distribution of produced neutro



50% flux in LT

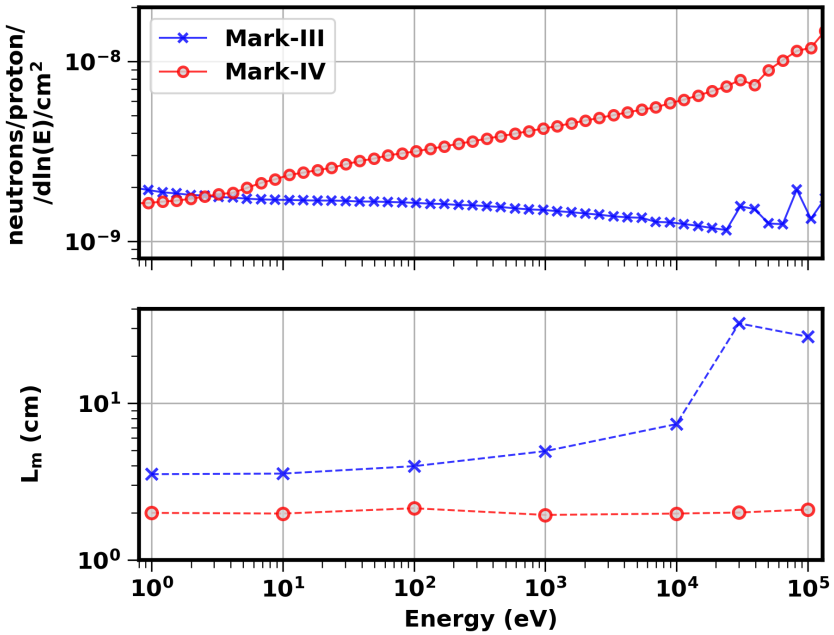
75% flux in LT

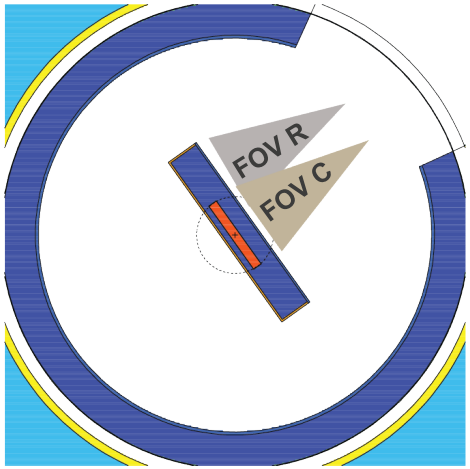


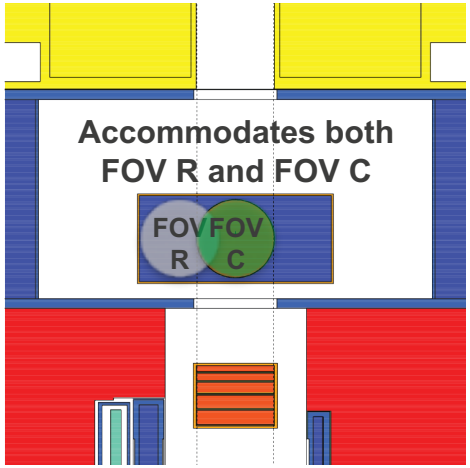


Compact disk target

- **Proposed design of the compact disk target provides:**
  - Substantial increase in the keV-to-MeV neutron flux
  - Significant reduction of the time resolution in both FWHM and tails of the distribution



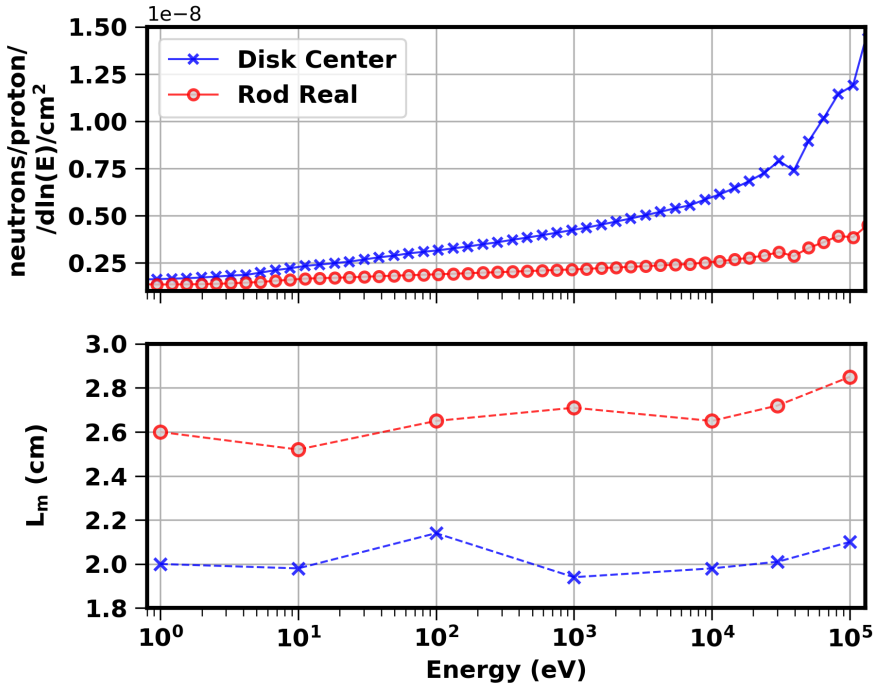


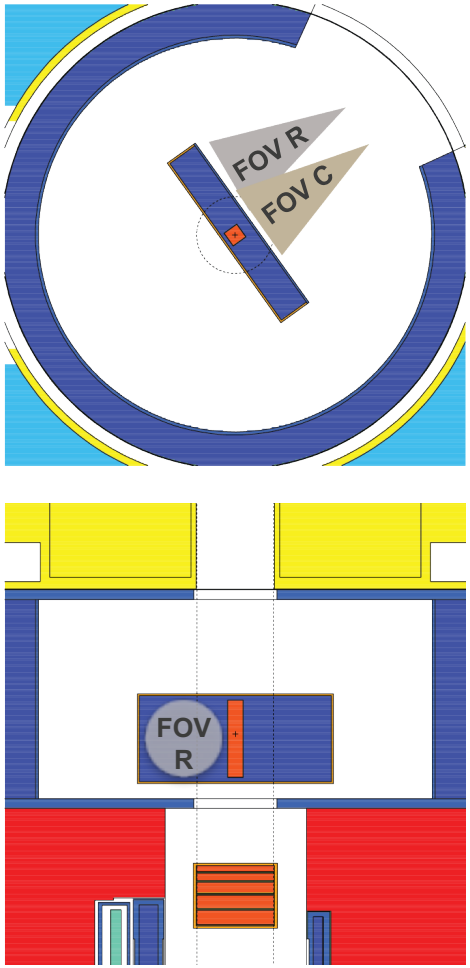


- **Thermal flux in LT is 72% relative to Mark-III without affecting background or time resolution**
- **This is a preferred design for Centered FOV**

Compact rod target

- **The main advantages of the compact rod target:**
  - Significant reduction of the gamma flash
  - More uniform distribution of neutrons in Real FOV

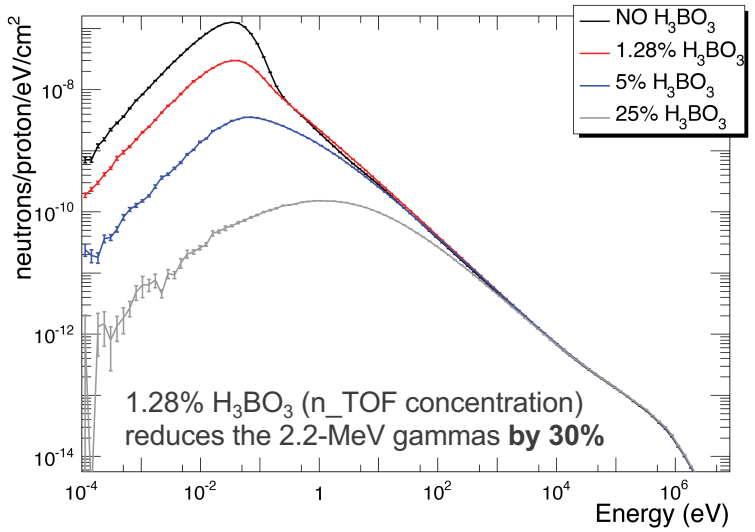


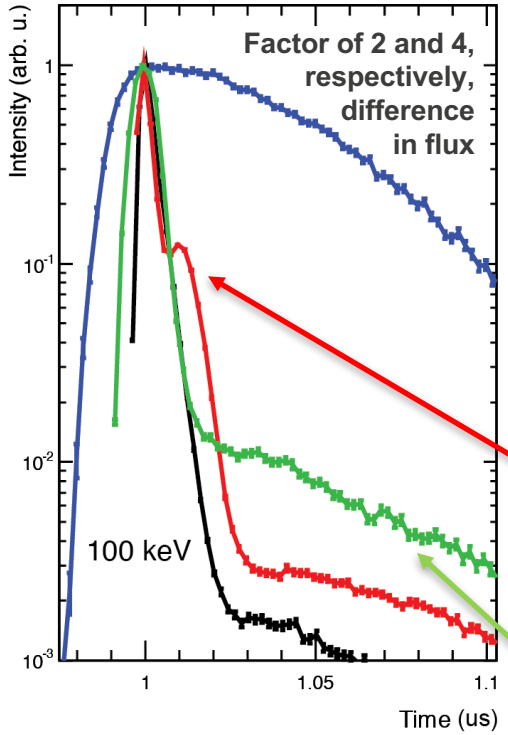


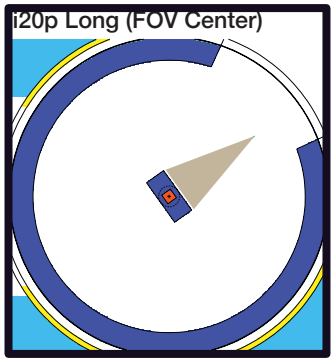
- **Thermal flux in LT is 74% relative to Mark-III without affecting background or time resolution**
- **This is a preferred design for Real FOV**

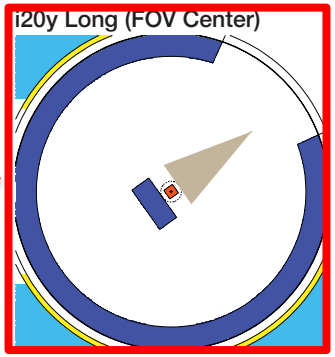
Compact rod target coupled with water moderator

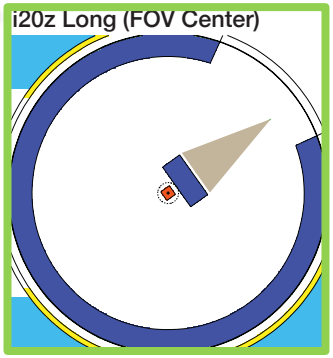
- **Rod target was used for various design studies:**
  - Water moderator position and thickness
  - Addition of H_3BO_3 into water moderator
  - Role of additional reflector (Be, Pb)

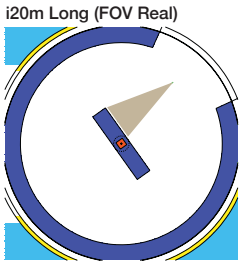


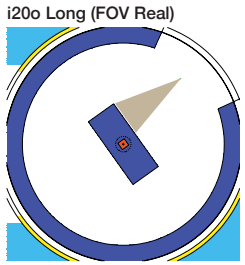


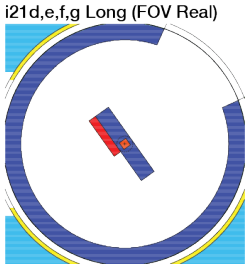


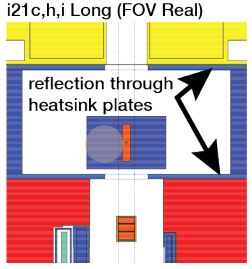






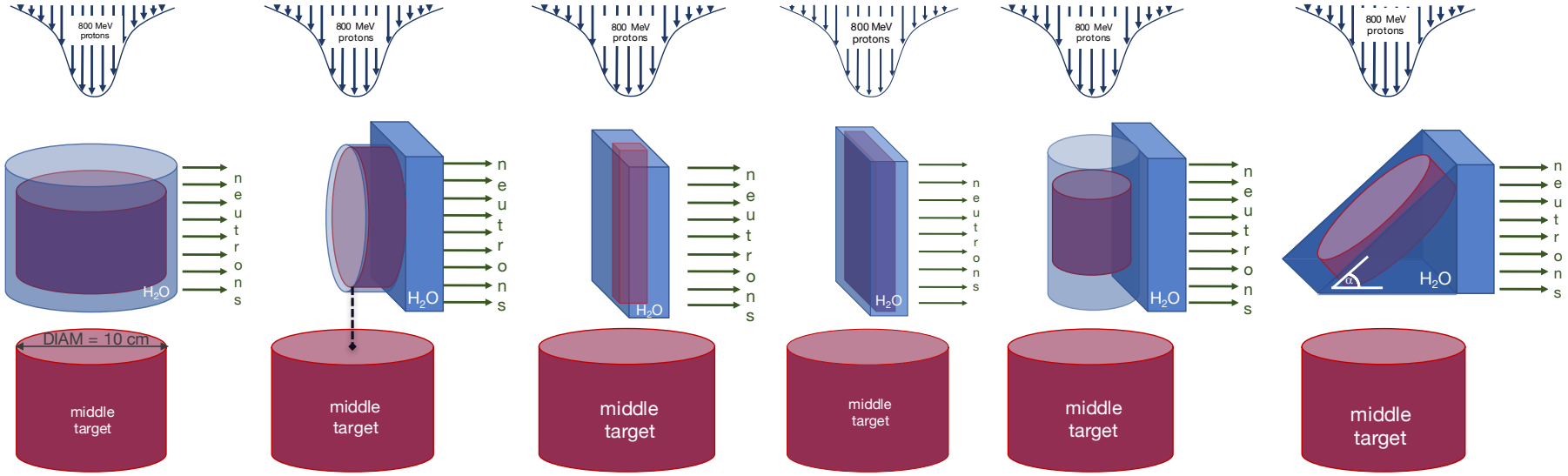






Additional target designs

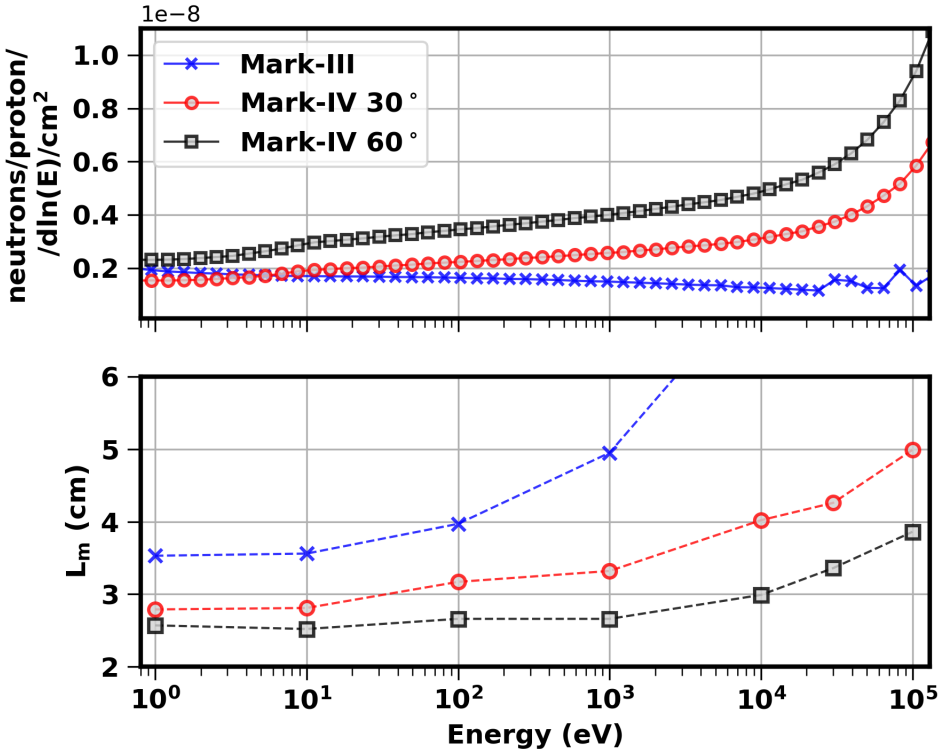
- **The main constraints on the new target design:**
  - Costs
  - Spatial limits
  - Engineering requirements (materials, robustness, cooling)
  - Operational perspective (simplicity, **in**sensitivity to proton beam position)
  - Leave ~75% of the thermal neutron flux for the lower tier relatively to Mark-III
  - No additional major impacts on material science (resolution, background)

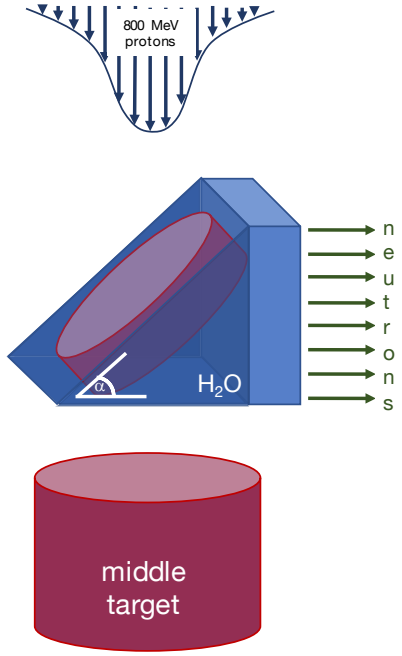


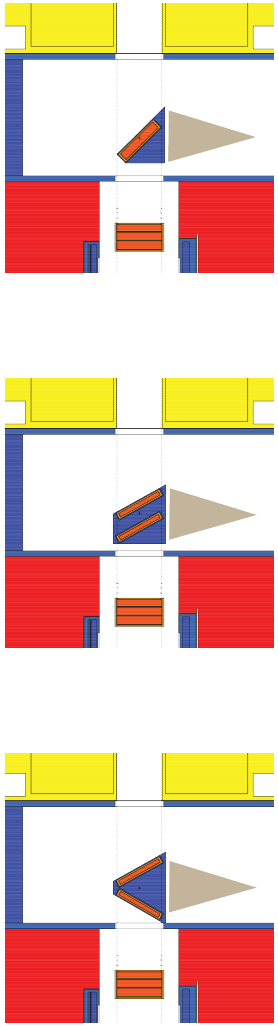
Disk targets at 30º, 45º, and 60º

- **Pros and cons in the upper tier:**
  - ✓ Insensitive to the proton beam position
  - ✗ Moderate increase in flux
  - ✗ Resolution is not impressive

- **Flux in lower tier:**
  78% **& 67%**
  relative to Mark-III:



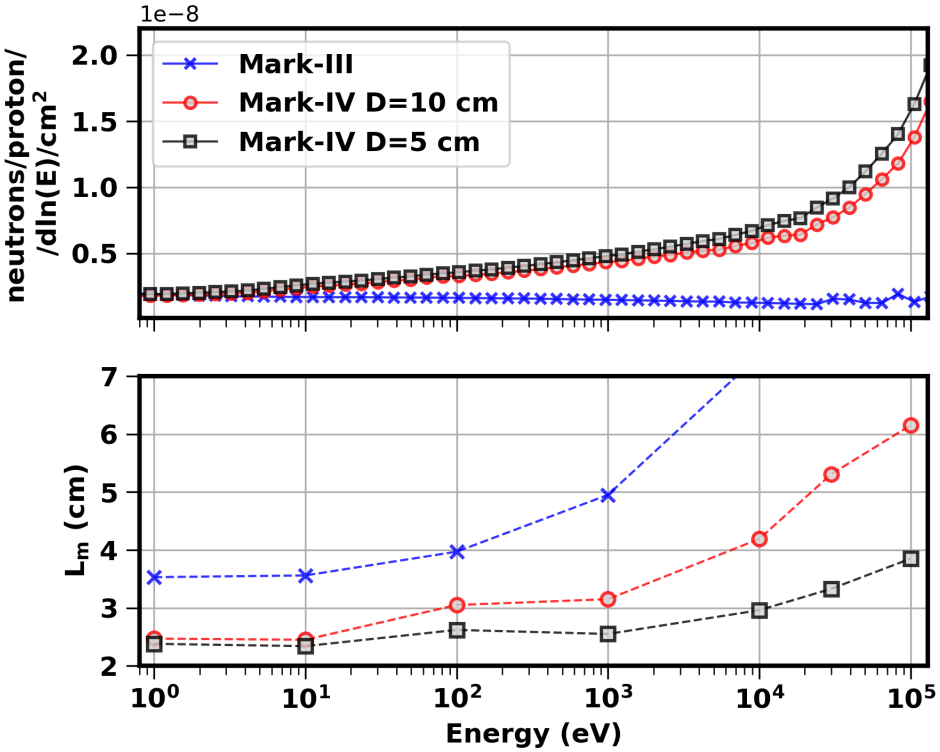


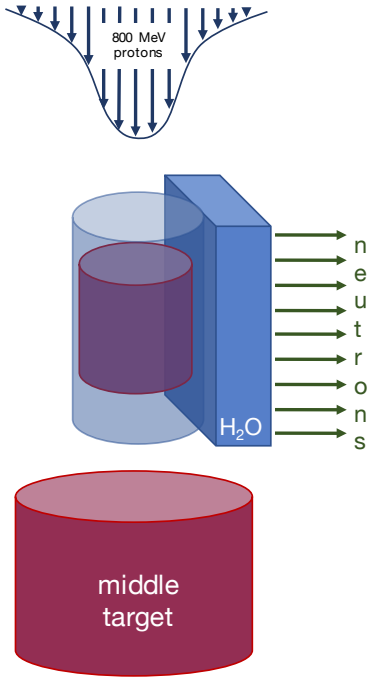


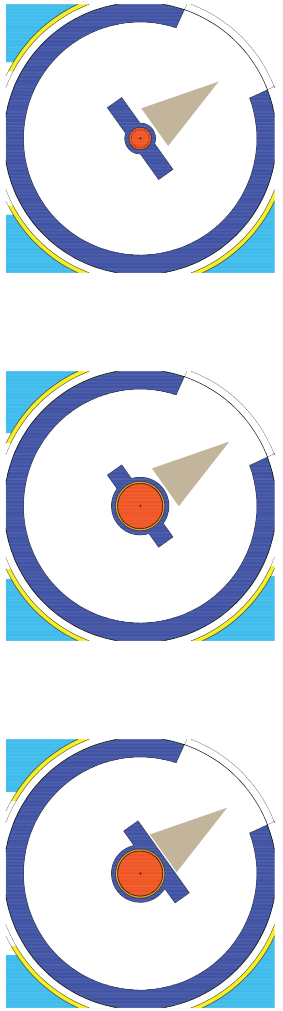
Cylindrical target with wings

- **Pros and cons in the upper tier:**
  - ✓ Insensitive to the proton beam position
  - ✗ Moderate increase in flux
  - ✗ Resolution is not impressive

- **Flux in lower tier:**
  65%
  relative to Mark-III:

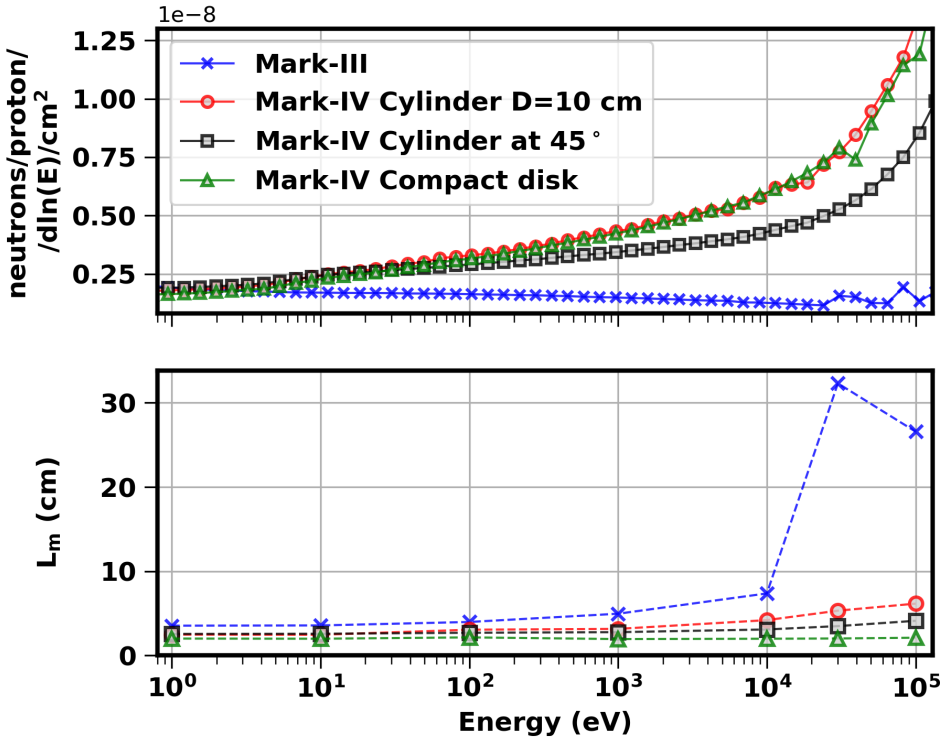






Summary of alternative target designs

- A wide range of various target designs has been studied with respect to the previously mentioned constraints
- The optimization process has resulted in finding the solution in the space of many independent (often contradict) variables
- None of the alternative designs reaches the performance of the compact disk target



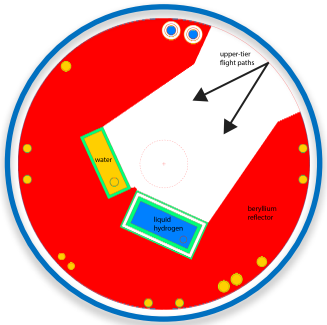
Flux in lower tier

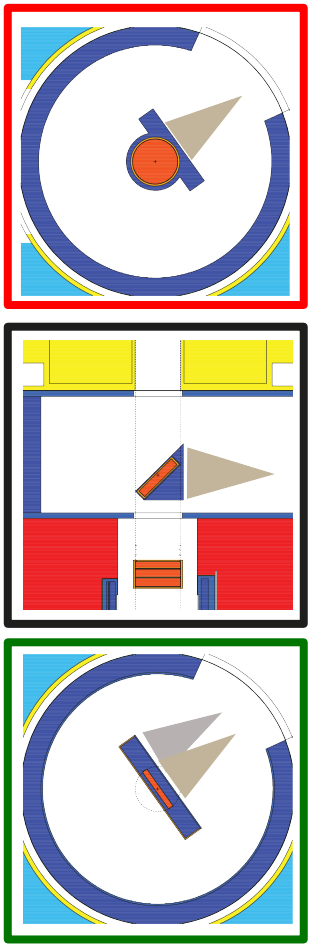
65%

73%

72%

relative to Mark-III





Conclusion

- **We developed a target design with the following characteristics in**
- **Upper tier:**
  - Superior resolution and
  - Significant gain in the keV-to-MeV energy range
- **Lower tier:**
  - ~75% of the thermal flux relative to Mark-III
  - **NO** impact on time resolution
  - **NO** change in background

- **The target design complies with the requirements on**
  - Costs
  - Simplicity
    - Engineering
    - Manufacturing
    - Operational
- **Great experimental results are expected**

Thank you for your attention.

Backup slides

- **No water moderator (o22p)**